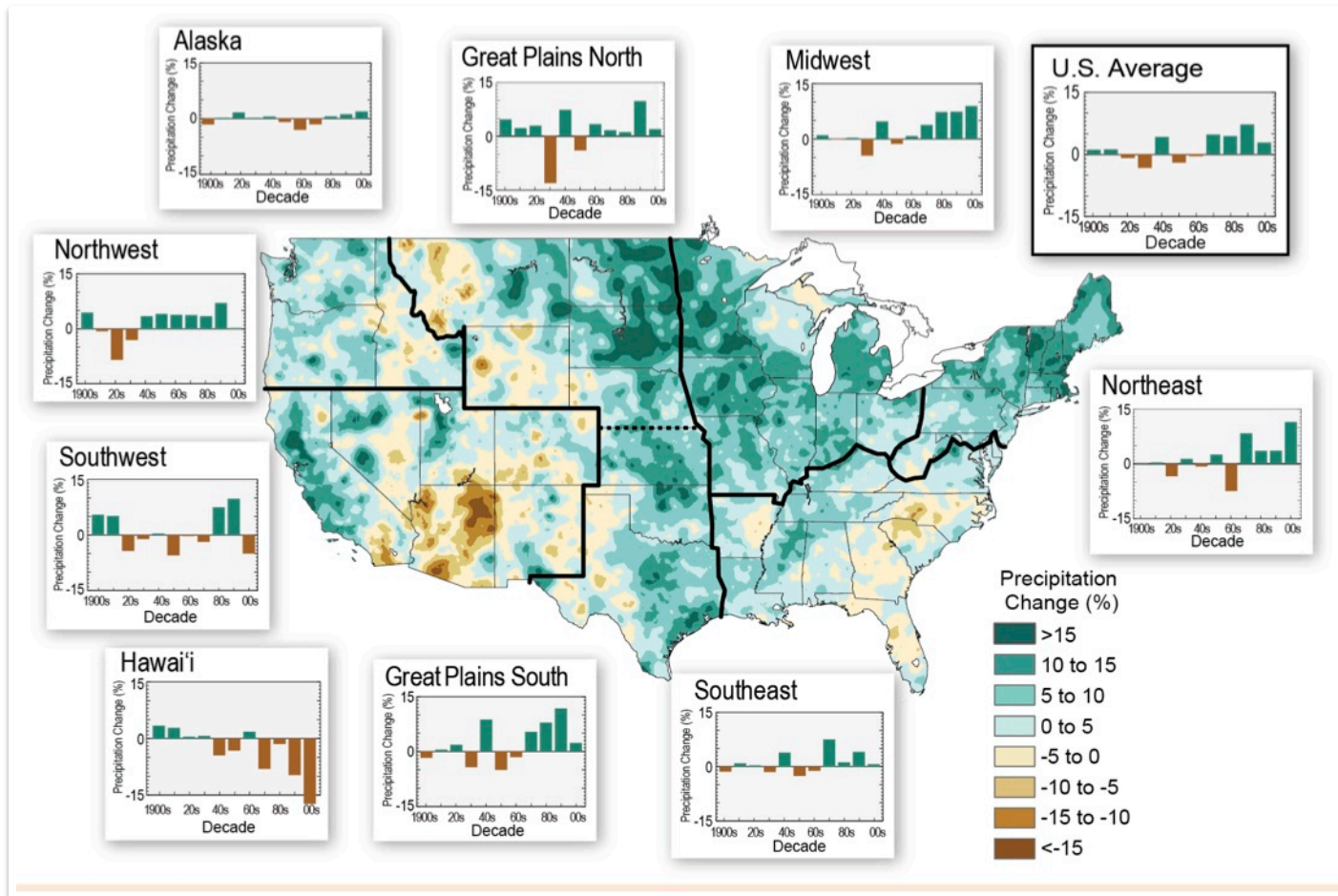


# Characterizing the Increase in U.S. Heavy Precipitation Events

Martin Hoerling, Jon Eischeid, Xiaowei  
Quan and Judith Perlwitz

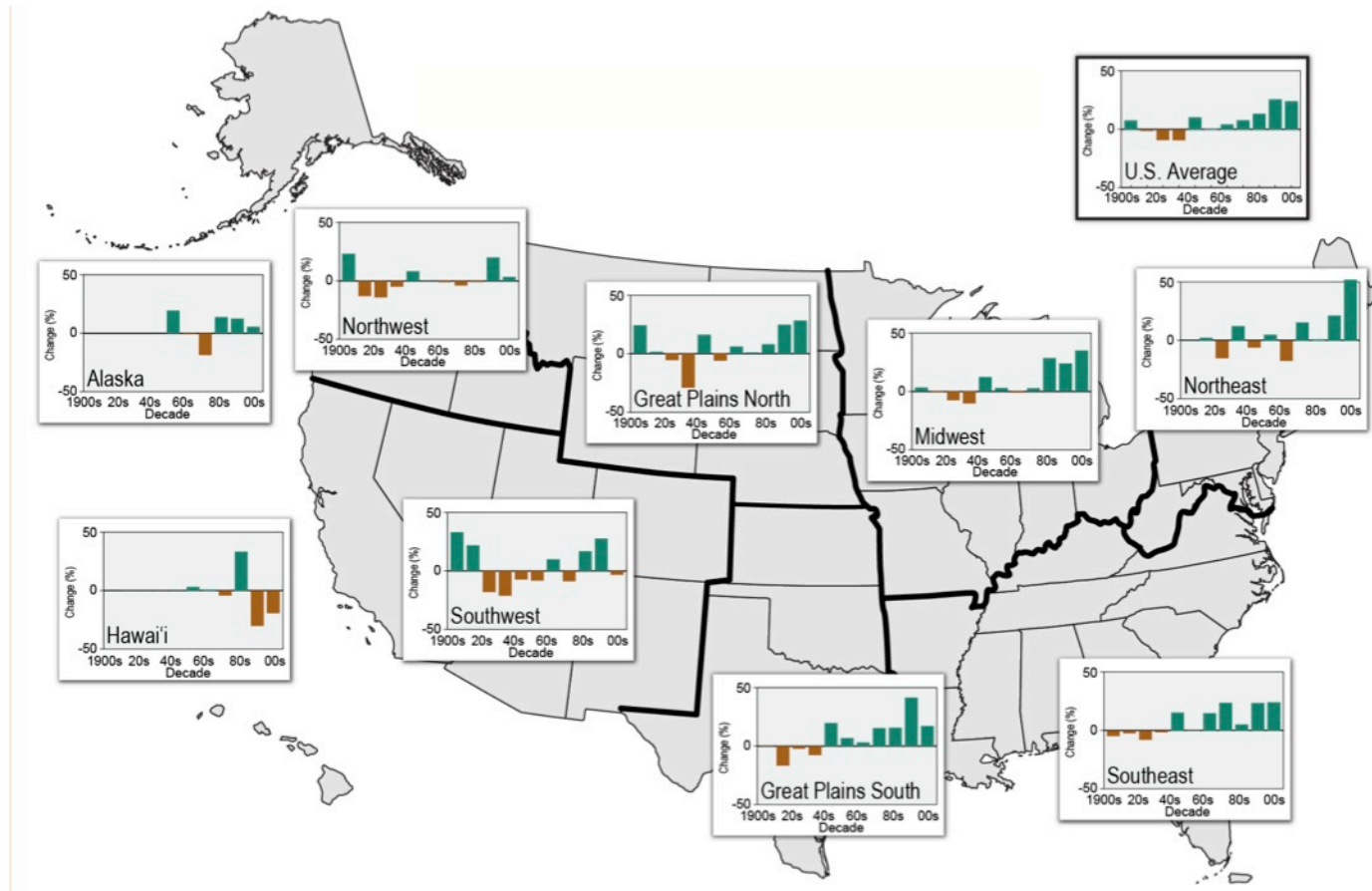
NOAA Earth System Research  
Laboratory Physical Sciences Division

# Average U.S. Precipitation has Increased by 5% since 1900



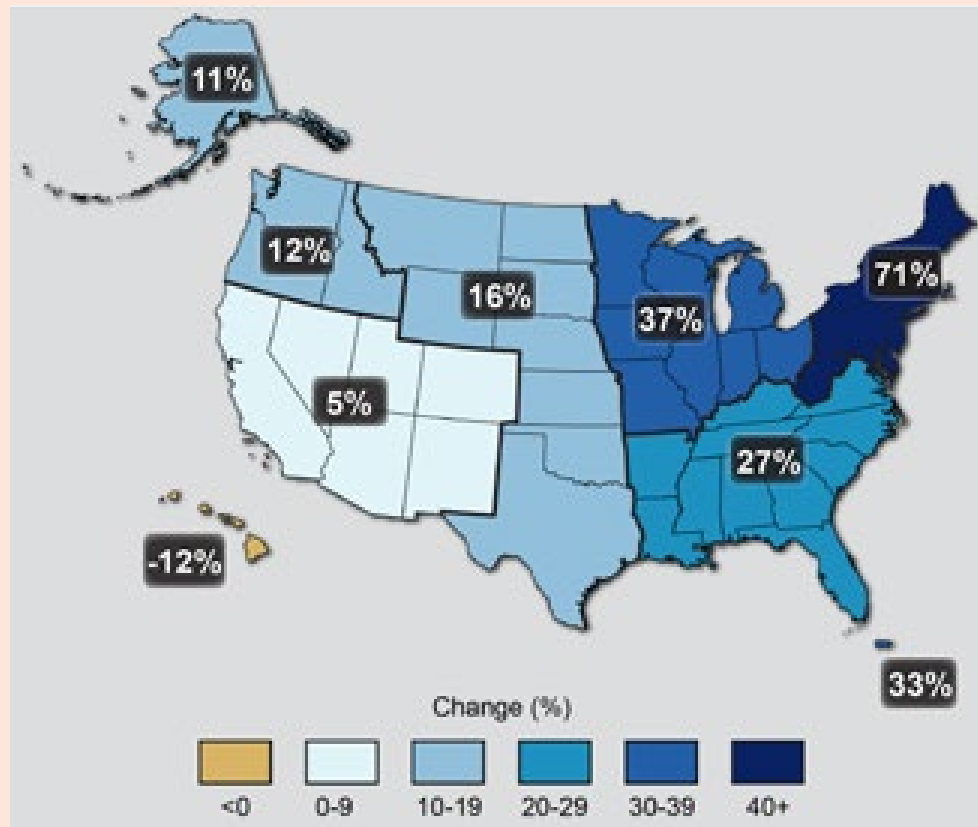
Source: U.S. National Assessment Report 2014

# Heaviest Rainfall Events Have Become Heavier and More Frequent



Source: U.S. National Assessment Report 2014

## Observed Change in Very Heavy Precipitation

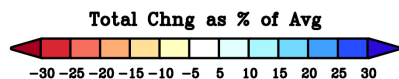
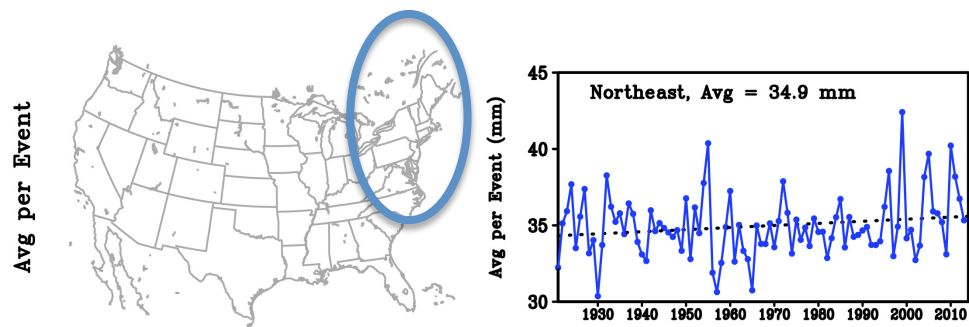
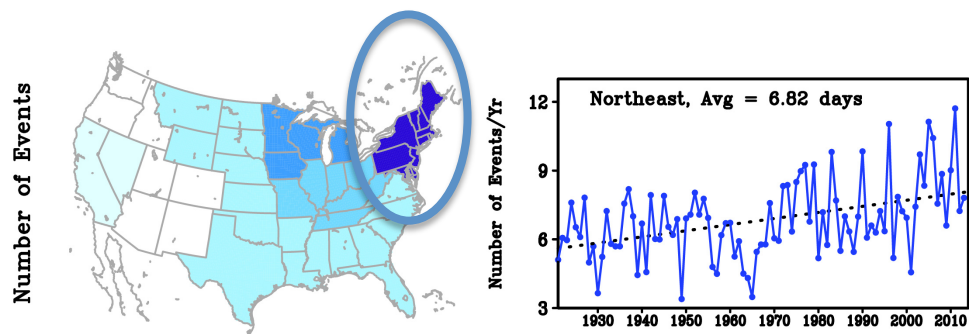
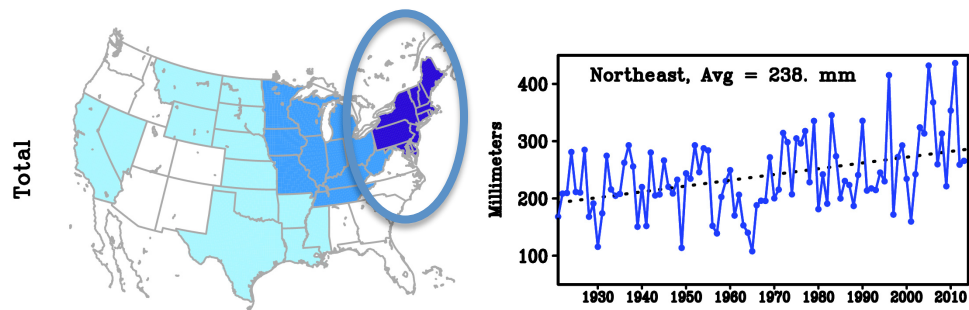


**Figure 2.18.** The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. These trends are larger than natural variations for the Northeast, Midwest, Puerto Rico, Southeast, Great Plains, and Alaska. The trends are not larger than natural variations for the Southwest, Hawai'i, and the Northwest. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: updated from Karl et al. 2009<sup>1</sup>).

# Motivation

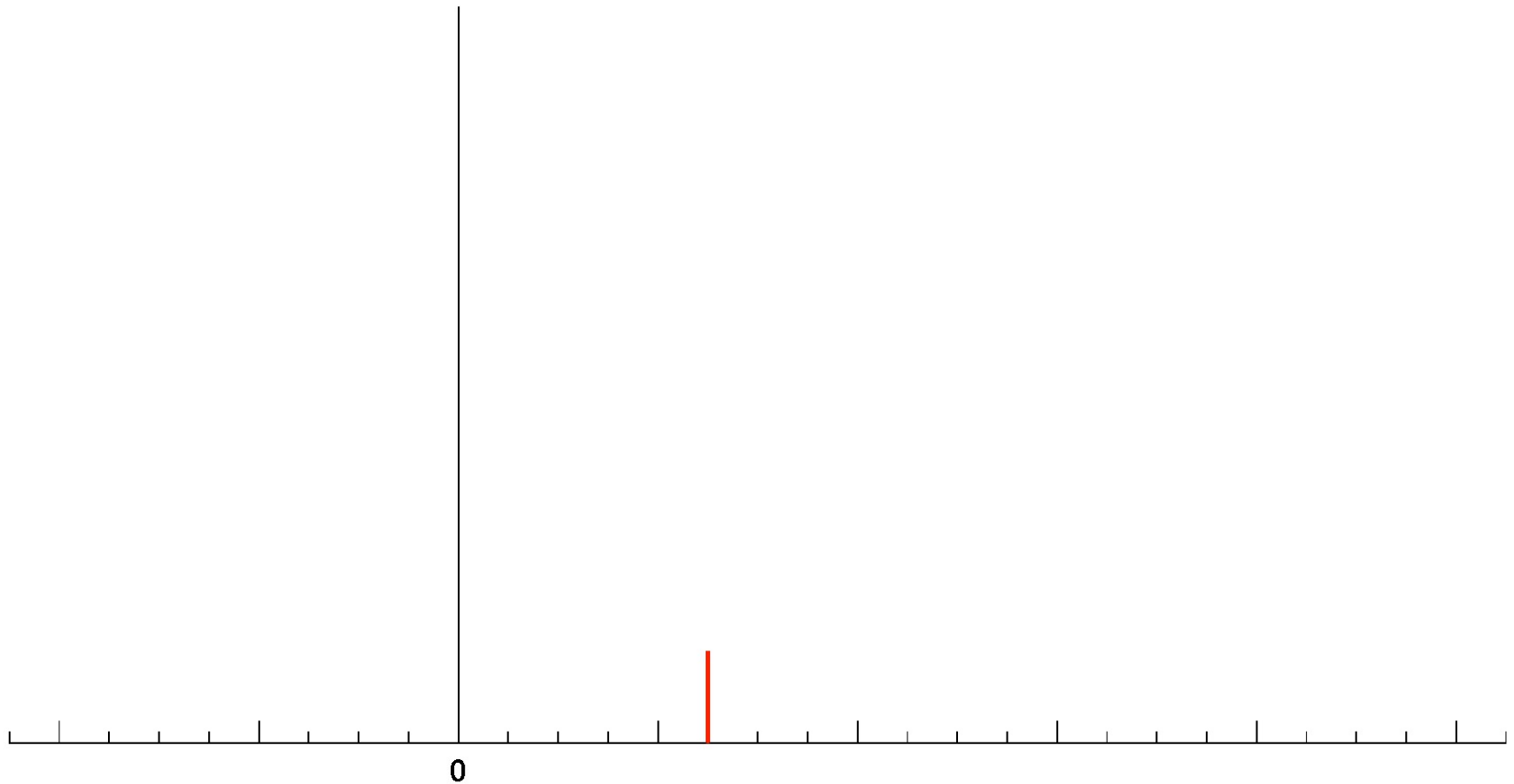
- Observational record alone is not sufficient to characterize recent precipitation change.
- Large model ensemble approach is well suited to determine factors that cause changes in heavy precipitation in the U.S.

# Observed Changes in Very Wet Days since 1921\*

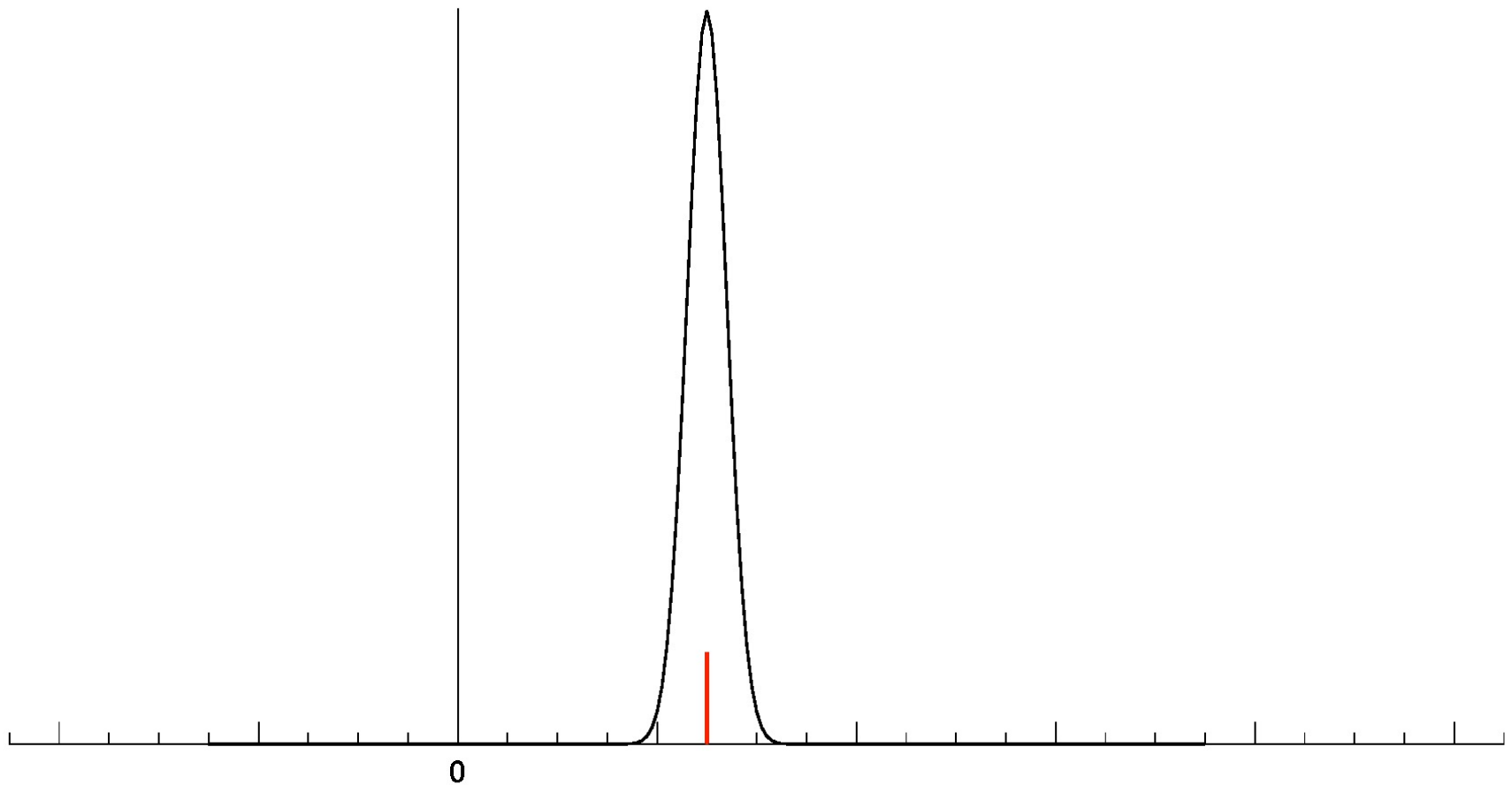


\* 95<sup>th</sup> Percentile Derived from 1921-1980 GHCN-Daily (Menne et al. 2012)

# How to Characterize the Upward Trend in Extreme Precipitation?



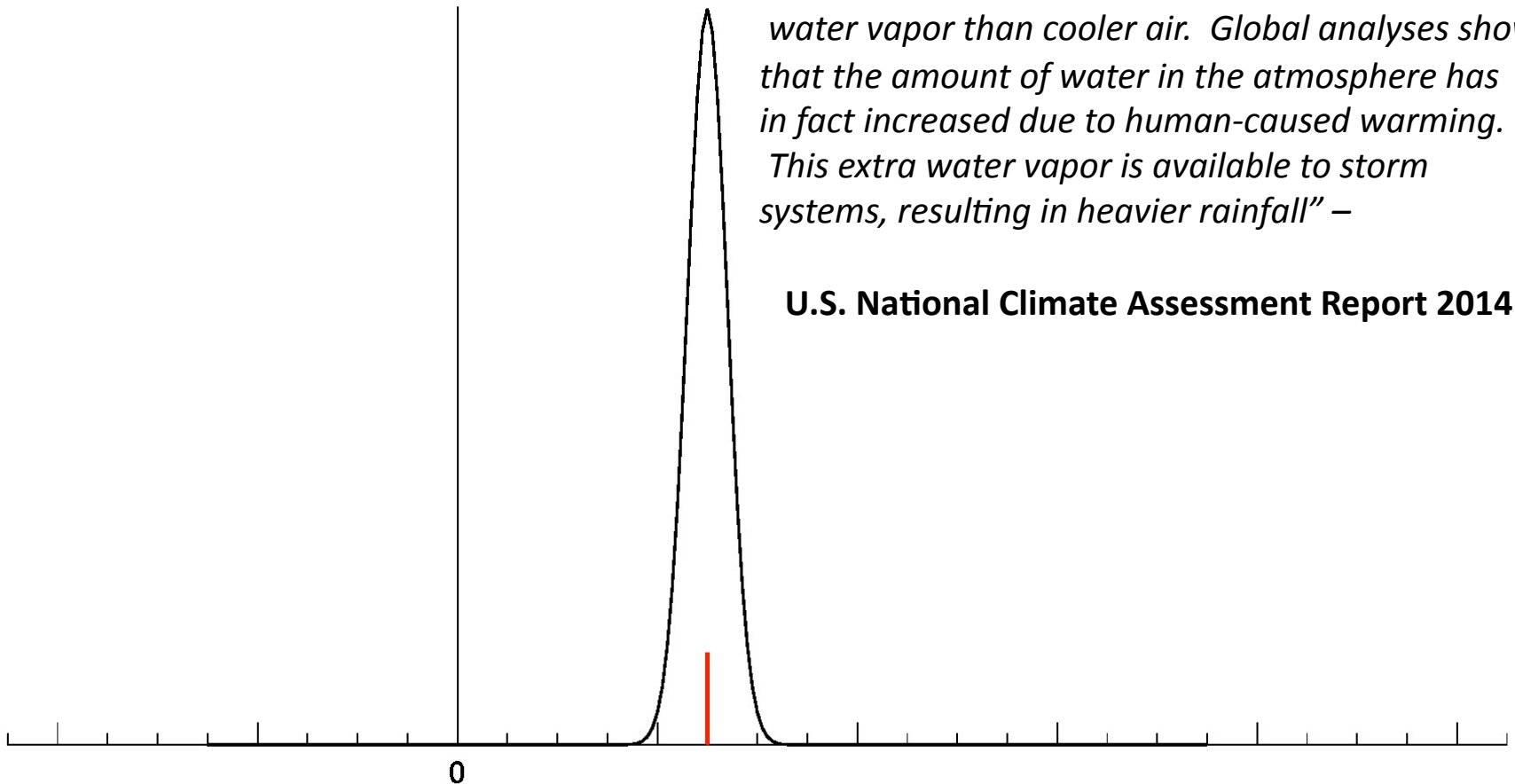
## A Largely Deterministic Response to Forcing?



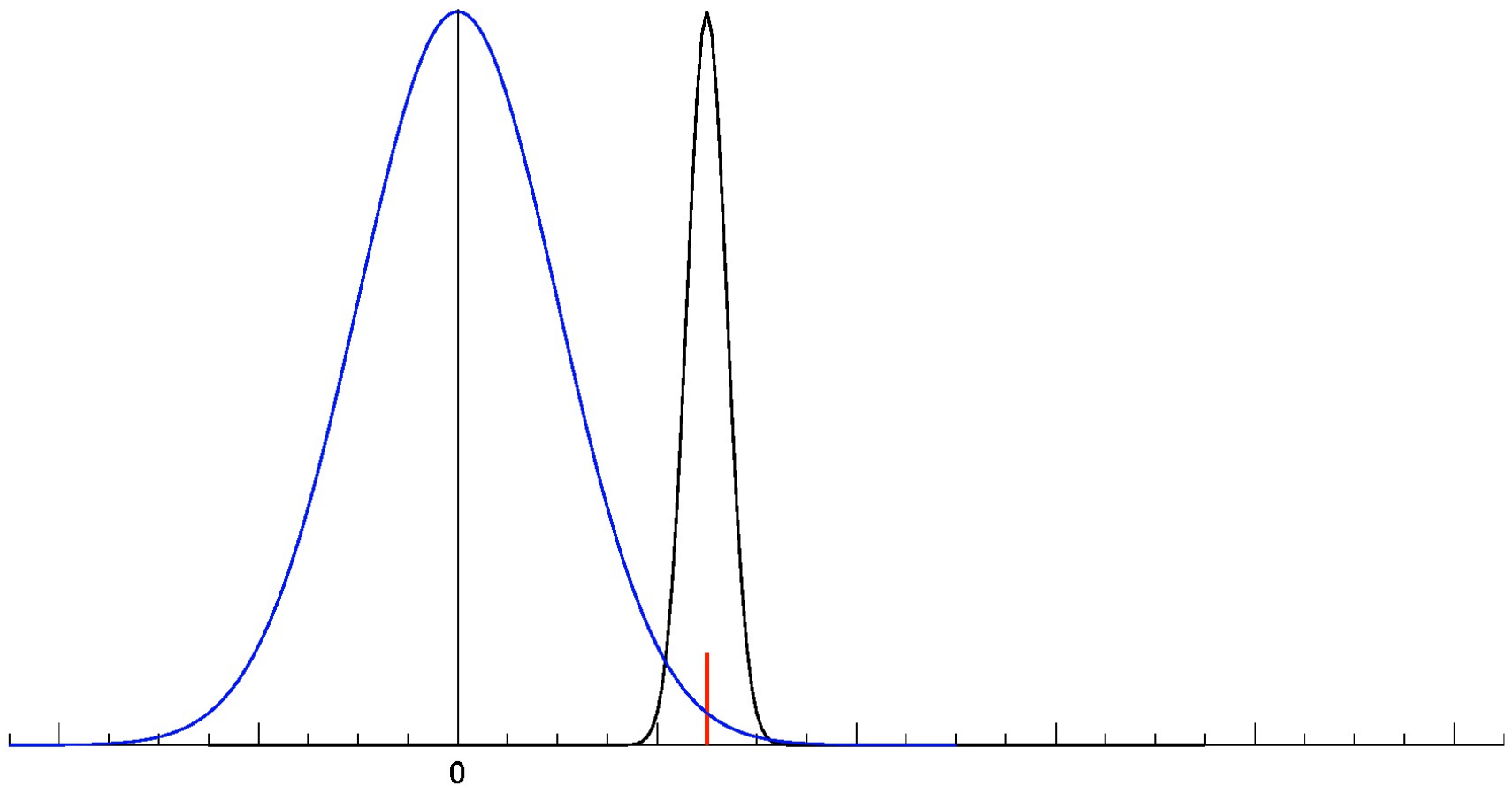
## A Largely Deterministic Response to Forcing?

*“The mechanism driving these changes is well-understood. Warmer air can contain more water vapor than cooler air. Global analyses show that the amount of water in the atmosphere has in fact increased due to human-caused warming. This extra water vapor is available to storm systems, resulting in heavier rainfall” –*

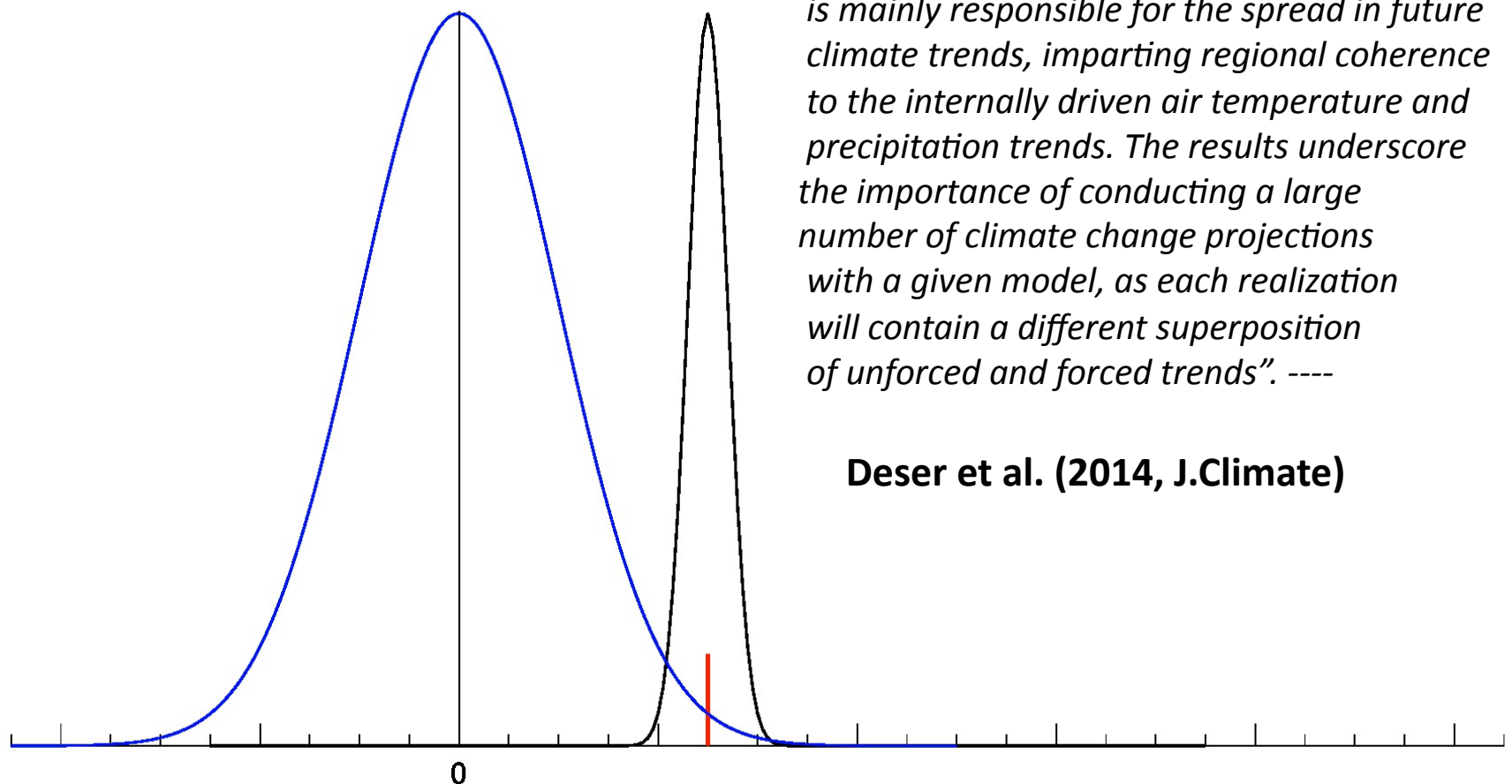
**U.S. National Climate Assessment Report 2014**



# An “Extreme” Manifestation of Internal Coupled Variability?



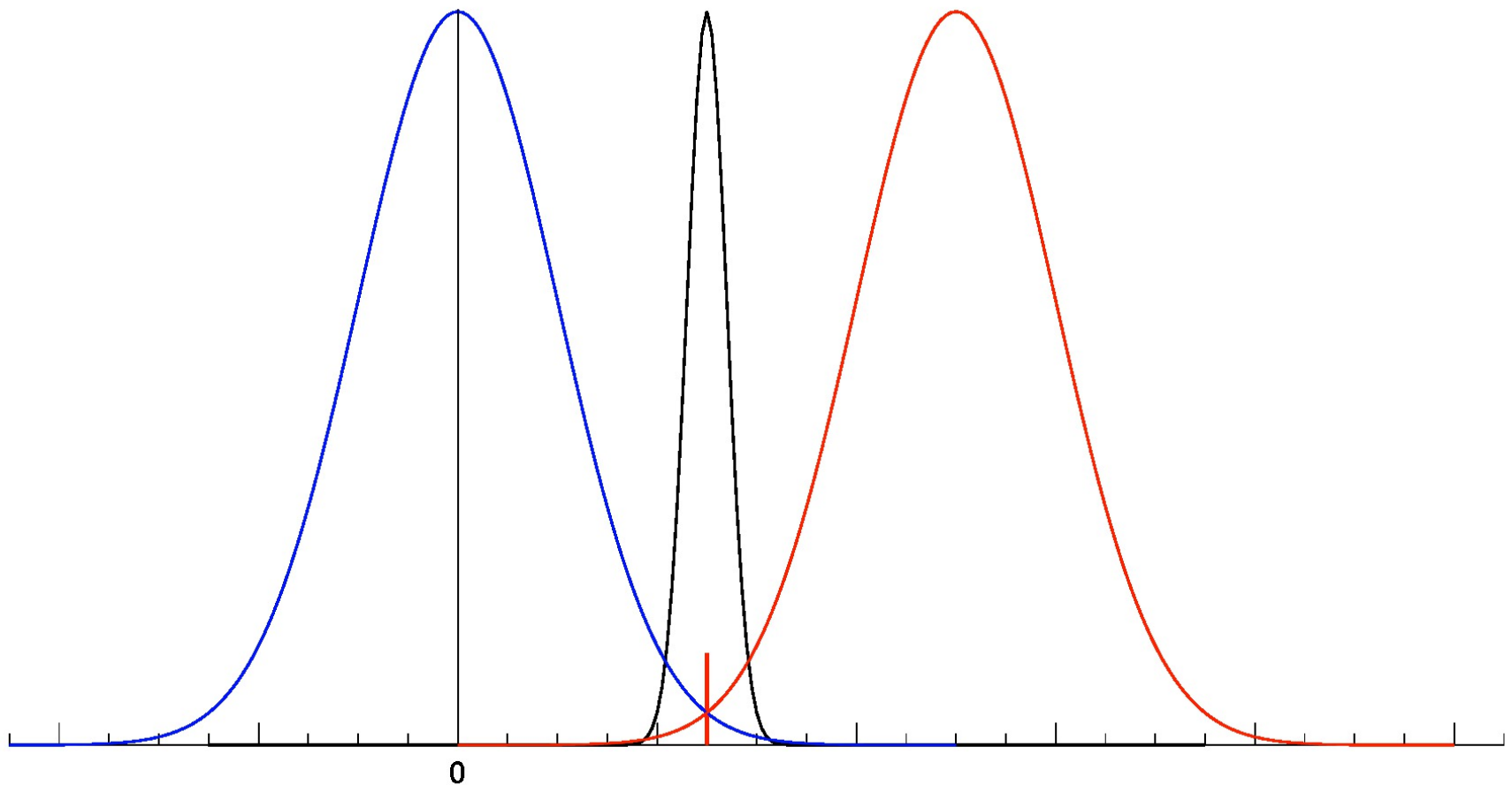
## An “Extreme” Manifestation of Internal Variability?



*“Intrinsic atmospheric circulation variability is mainly responsible for the spread in future climate trends, imparting regional coherence to the internally driven air temperature and precipitation trends. The results underscore the importance of conducting a large number of climate change projections with a given model, as each realization will contain a different superposition of unforced and forced trends”. ----*

**Deser et al. (2014, J.Climate)**

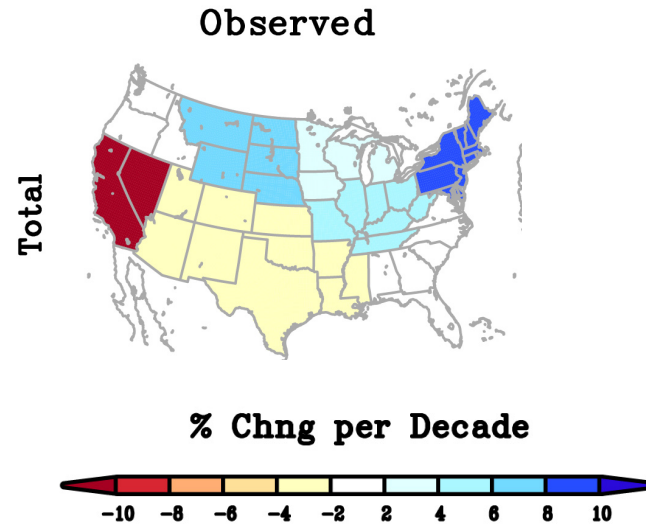
**An “Extreme” Manifestation of Internal Variability---  
Superposed Upon a Strong Forced Signal?**



# Coupled and Uncoupled Climate Model Simulations 1979-2013 with CCSM4/CAM4

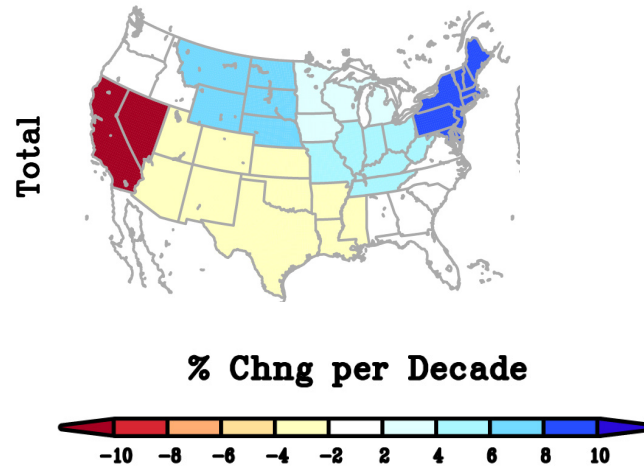
- ° CCSM4 (Coupled)..... 20 member
- ° CAM4 (C-AMIP) ..... 20 member  
Specify varying SST/sea ice/radiative forcing from each CCSM4 trace
- ° CAM4 (O-AMIP)..... 20-member
- ° CAM4 (CCSM4 Trace 10)..... 20 member
- ° CAM4 (CCSM4 Trace 14)..... 20 member

# Change in very wet days (95%) 1979-2013

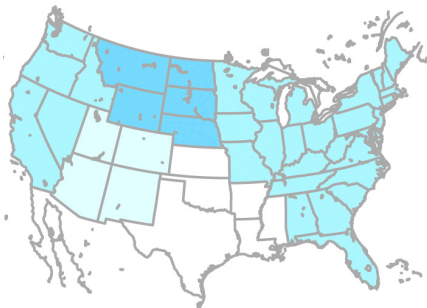


# Change in very wet days (95%) 1979-2013

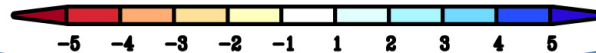
Observed



CCSM4

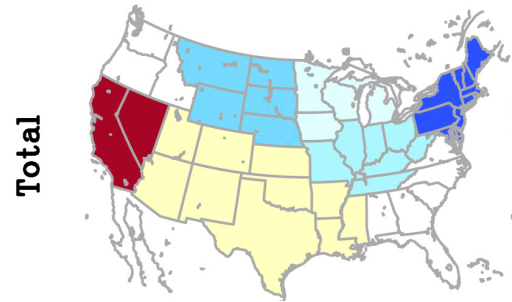


% Chng per Decade

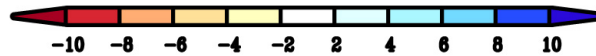


# Change in very wet days (95%) 1979-2013

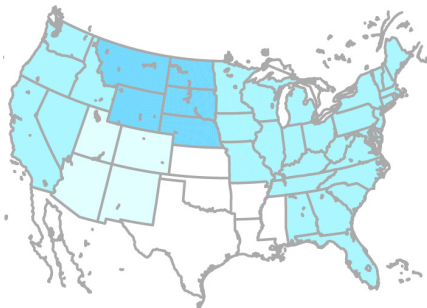
Observed



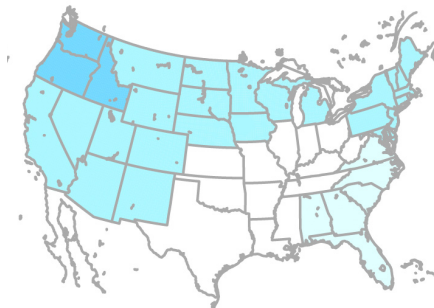
% Chng per Decade



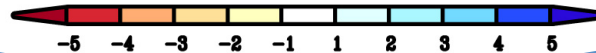
CCSM4



CAM4-C

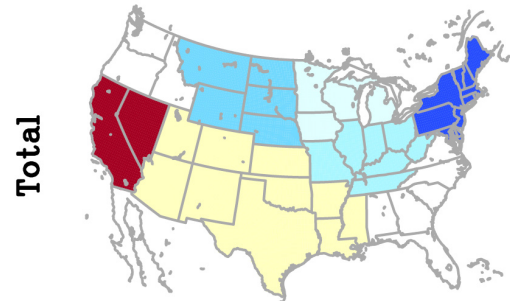


% Chng per Decade

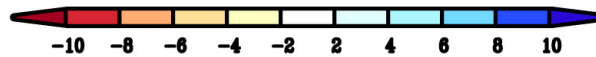


# Change in very wet days (95%) 1979-2013

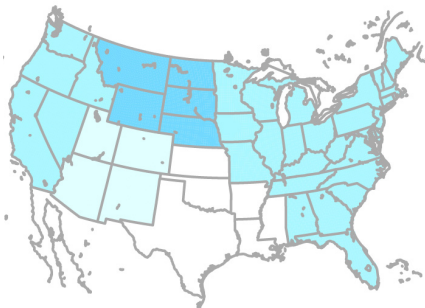
Observed



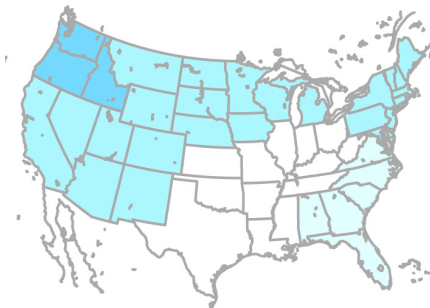
% Chng per Decade



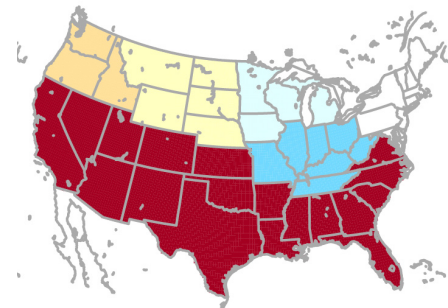
CCSM4



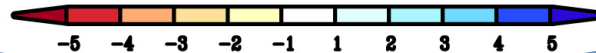
CAM4-C



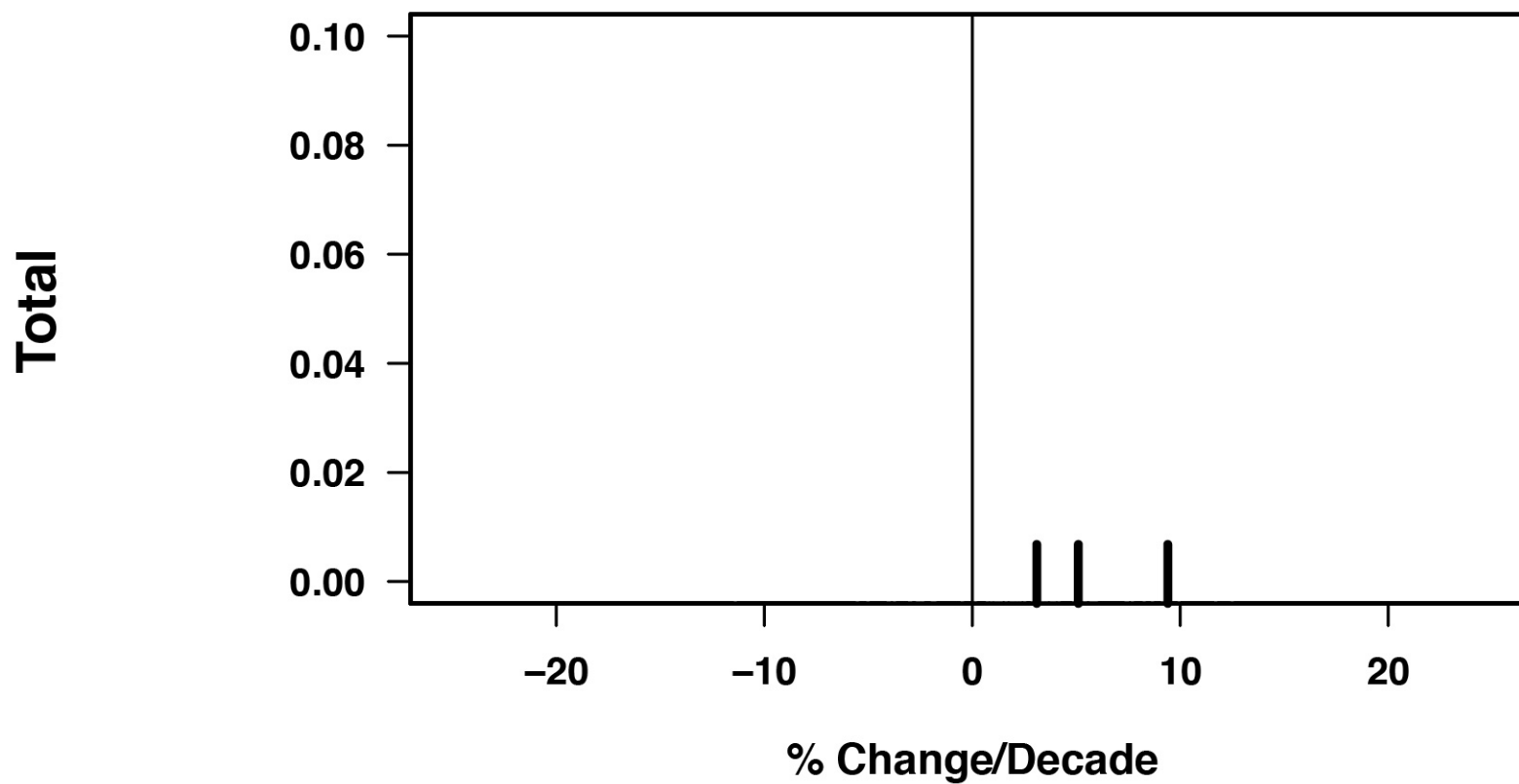
CAM4-O



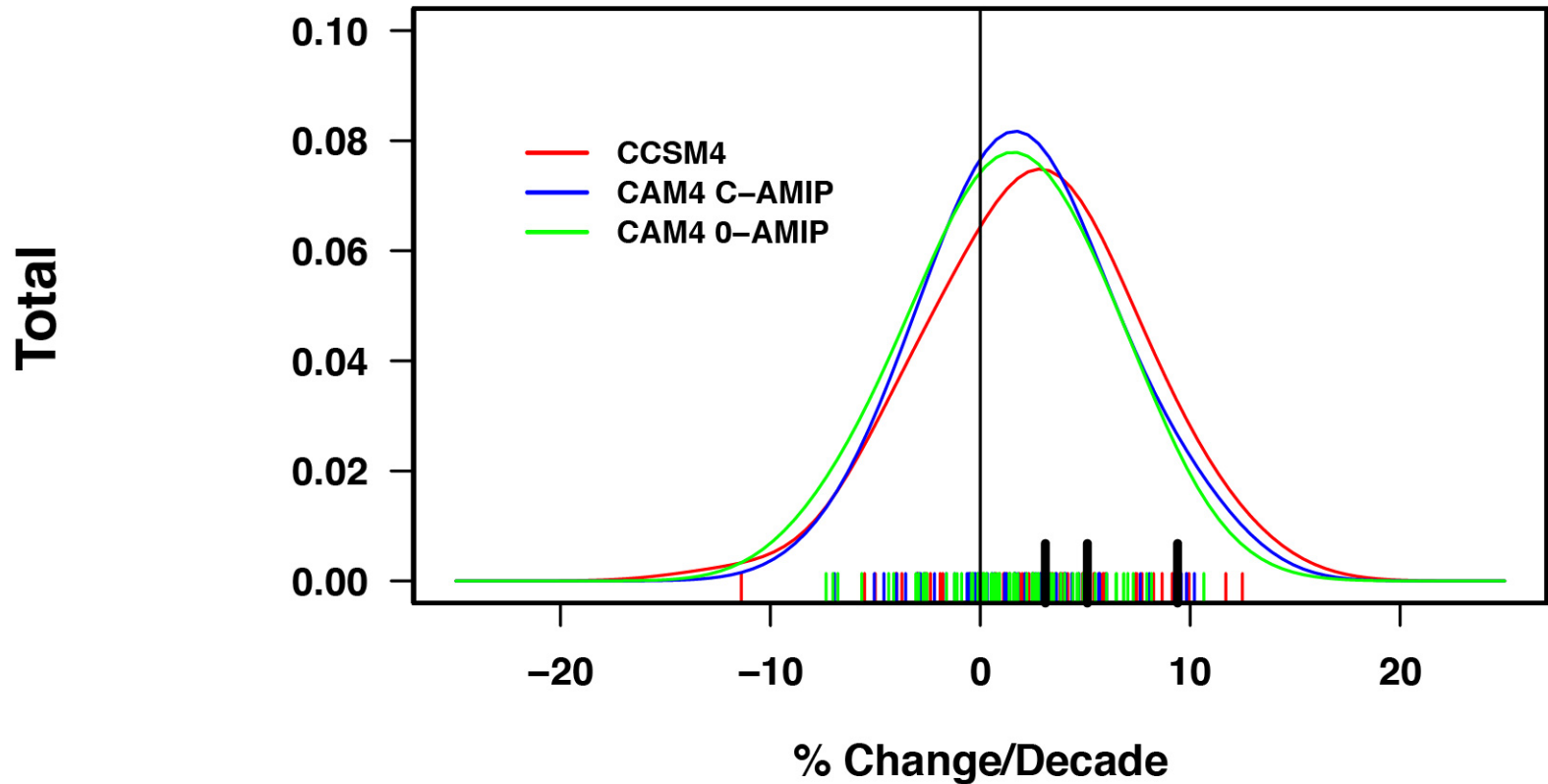
% Chng per Decade



## Change in PPT at the 95% Level North Central/Northeast Region



# Change in PPT at the 95% Level North Central/Northeast Region



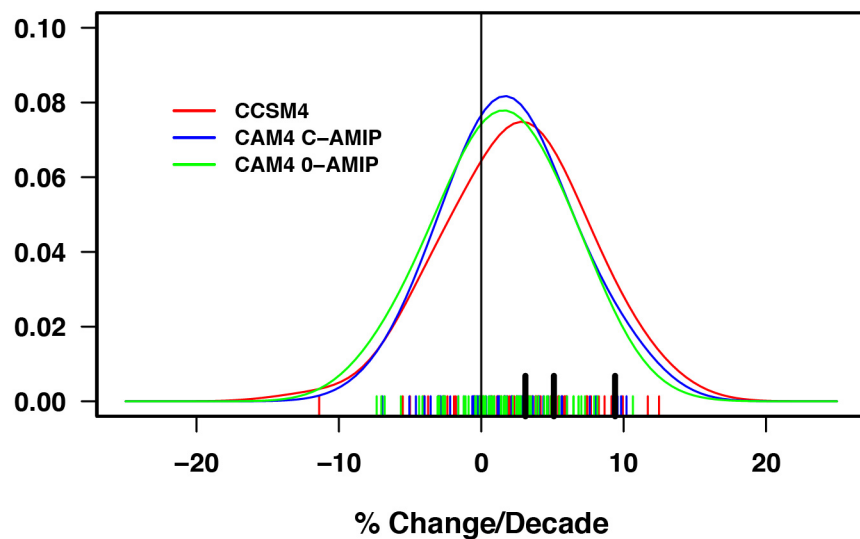
# Interpretation of Simulations

## *vis-à-vis the Observed Upward Trend in Very Wet Days Over the Northern US (1979-2013)*

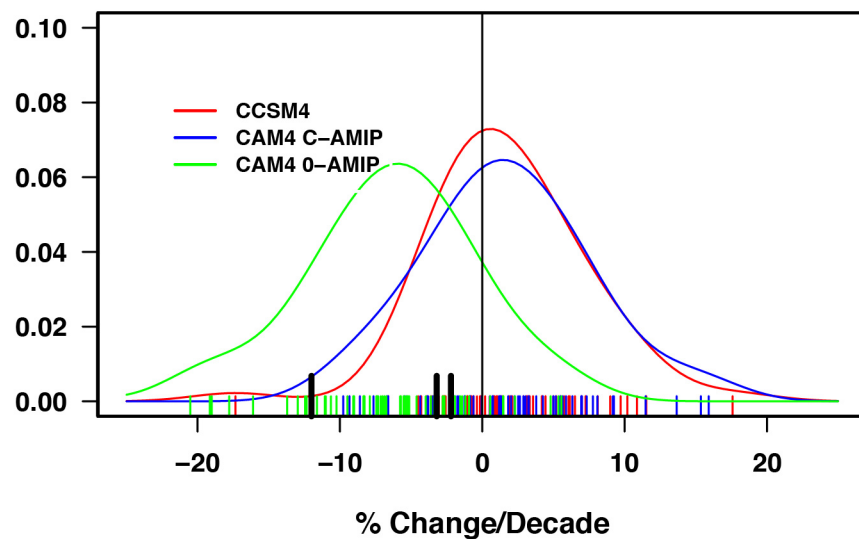
- ° **There exists a forced signal toward increased pcpn falling in the upper 95<sup>th</sup> percentile**  
*Forced signal of extreme wetness mostly via increase # of events, a characteristic of observed changes.*
- ° **Climate system noise ~ double the forced signal magnitude in very wet day trends**  
*Owing to large internal variability, observed changes are unlikely to have been strongly forced.*
- ° **Statistics of change in extreme wet days for O-AMIP and C-AMIP are indistinguishable.**  
*Equally plausible that observed upward trend is a sample drawn from an externally-forced population as it is a sample drawn from a population forced by the particular trace of obs SST variation.*

# Comparison between North Central/Northeast Region and South/Southwest Region

**Change in PPT at the 95% Level  
North Central/Northeast Region**

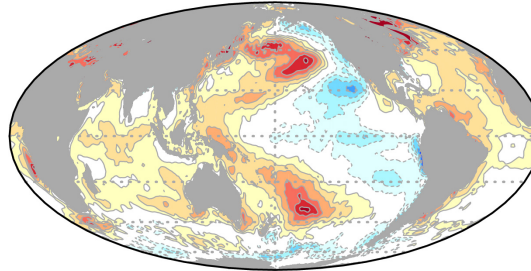


**Change in PPT at the 95% Level  
South/Southwest Region**

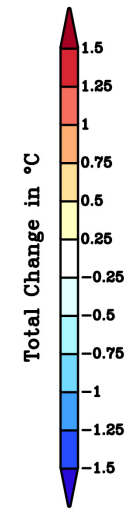
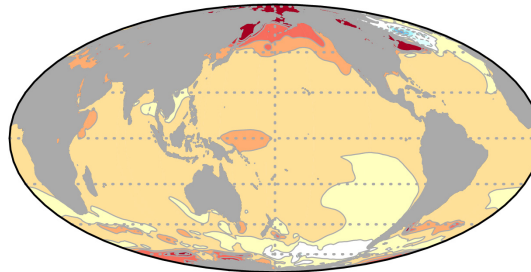


# Annual SST Change: 1979–2013

Observed

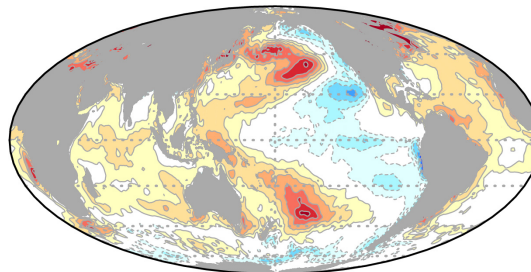


CCSM4

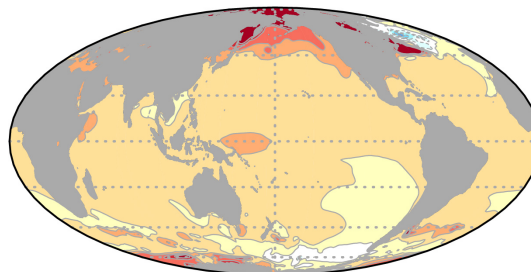


# Annual SST Change: 1979–2013

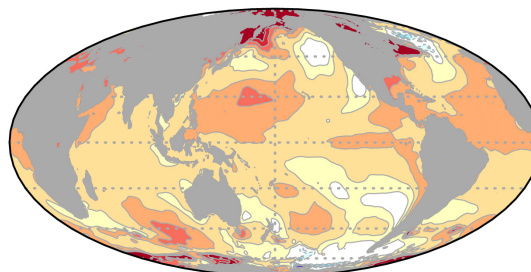
Observed



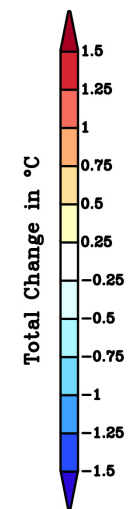
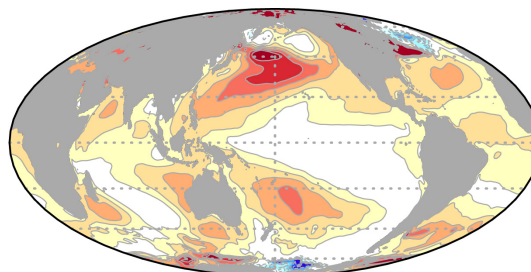
CCSM4



CAM4 Trace 10

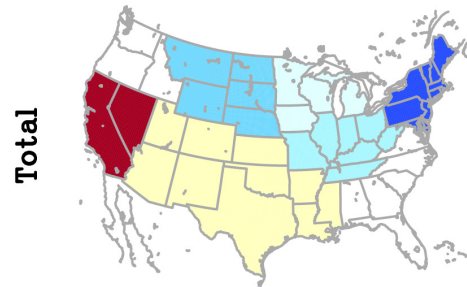


CAM4 Trace 14

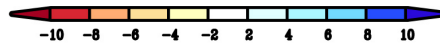


# Change in Very Wet Days (95%)

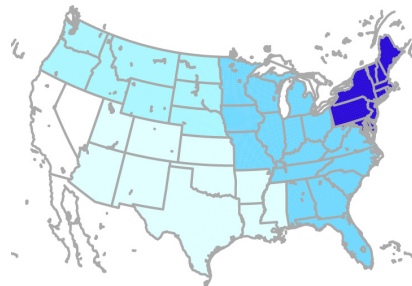
Observed



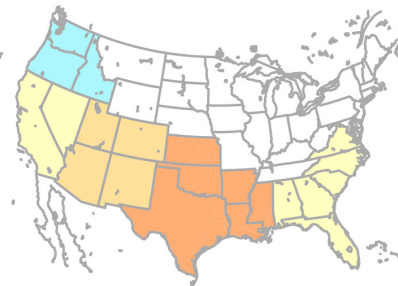
% Chng per Decade



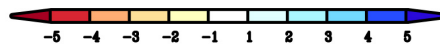
CAM4 Trace 10



CAM4-Trace 14



% Chng per Decade



# Some Closing Thoughts

## *On Trends in Very Wet Days Over the US (1979-2013)*

- ° **Various factors responsible for OBS regional pattern in trends of very wet days.**  
*Contrast between the northern and southern US unlikely reconcilable with GHG forcing alone*
- ° **The particular SST trace may have been more relevant than the particular GHG trace.**  
*Contiguous US pattern of very wet day trends appears most congruent with CAM4 (O-AMIP) footprint.*
- ° **Concerning the particular SST trace: An extreme “event” of internal variability?**  
*No CMIP5 model (37) yields OBS strong increase in Indo-Pacific SST gradient during 1979-2013.*